# Combining Discrete Element Modeling, Finite Element Analysis, and Experimental Calibrations for Modeling of Granular Material Systems, Phase I

Completed Technology Project (2007 - 2008)

## Project Introduction

The current state-of-the-art in DEM modeling has two major limitations which must be overcome to ensure that the technique can be useful to NASA engineers and the commercial sector: the computational intensive nature of the software, and the lack of an established methodology to determine the particle properties to best accurately model a given physical system. The proposed work will address both of these limitations. We will look at two approaches to overcome the particle count limitations of DEM: investigate the scaling up of particle size; and combine FEA and DEM to look at problems of densely packed solids. We will explore regimes where DEM and FEA are applicable and establish a coupling methodology that can be further developed during phase II. To address the lack of an established methodology to determine the particle properties to best accurately model a given physical system, we will investigate several small scale experiments that can be used to characterize DEM models. The proposed work will advance the state-of-the-art in DEM. At the end of phase I we will show the feasibility of developing modeling approaches to overcome the main limitations of DEM.

## Anticipated Benefits

Almost every industry handles one and often more bulk solids in production plants. In the chemical industry alone, an estimated 60% of products are manufactured as particulates, and another 20% use powders as ingredients to impart specific end-use properties. The US Department of Commerce has estimated the total economic impact of bulk solids products to be $1 trillion/year. Problems associated in plants that store, process or handle bulk solids are widespread and costly. Having a reliable predictive model to determine the behavior of bulk solids in industrial applications can avoid or fix many such problems. Some examples where a predictive model would be very beneficial to have are: seed storage and distribution, harvesting and spreaders in agriculture; cement mixing and earth moving equipment design in the construction industry; coal transport and catalytic cracking in the energy sector; powder mixing, tablet compaction and pill dispensing in the pharmaceutical industry; processing vessels, dryers, reactors in the chemical industry; and rock cutting, drag lines and conveying in the mining industry. Having an accurate computer model could save time and money in the design process and result in better products and lower risks. A robust, accurate simulation capability for bulk granular materials can help NASA in the prediction of stress/strain shearing and compaction response of insulation materials inside the annular space of large cryogenic liquid fuel storage tanks. The current insulation material degrades over each mission requiring frequent, costly replacement. By properly characterizing small samples of the insulation material and then combining DEM and FEA, a model of the insulation in the large tank can be created, which can help NASA evaluate alternative insulation materials with fewer costly physical tests and reduced uncertainty and risk. A


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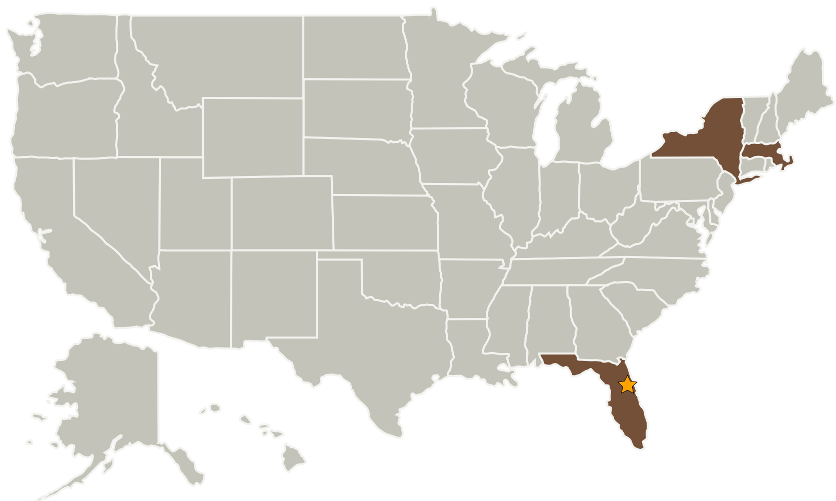
second application is to develop a computer model for the mechanical behavior of lunar soil during drilling and digging, construction and compaction (of berms), or during beneficiation and chemical processing of the soil (e.g., to remove water ice). It is impossible to reproduce the combination of lunar gravity and regolith in an earth-based experiment, so accurate computer models are critical. The success of future missions which involve construction and in-situ resource utilization on the moon or Mars will depend on the accuracy of the models.

### Primary U.S. Work Locations and Key Partners



| Organizations Performing Work | Role | Type | Location |
|---|---|---|---|
| ★Kennedy Space Center(KSC) | Lead Organization | NASA Center | Kennedy Space Center, Florida |
| Clarkson University, Division of Research | Supporting Organization | Academia | Potsdam, New York |
| Jenike & Johanson, Inc. | Supporting Organization | Industry | Tyngsboro, Massachusetts |

## Organizational Responsibility

**Responsible Mission Directorate:**

Space Technology Mission Directorate (STMD)

**Lead Center / Facility:**

Kennedy Space Center (KSC)

**Responsible Program:**

Small Business Innovation Research/Small Business Tech Transfer

## Project Management

**Program Director:**

Jason L Kessler

**Program Manager:**

Carlos Torrez

**Project Manager:**

Philip T Metzger

**Principal Investigator:**

Hayley Shen

## Technology Areas

**Primary:**

- TX09 Entry, Descent, and Landing
  - └ TX09.4 Vehicle Systems
    - └ TX09.4.5 Modeling and Simulation for EDL

| Primary U.S. Work Locations | |
|---|---|
| Florida | Massachusetts |
| New York | |